CURVE NUMBER AND GROUNDWATER RECHARGE CREDITS FOR LID FACILITIES IN NEW JERSEY

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Putting the LID on Stormwater Management, 2004

Dewberry

Introduction

- The State of New Jersey has been trying to encourage implementation of Low Impact Development (LID).
- At the same time, the state is requiring that the post-development groundwater recharge volumes must match those of the pre-development natural conditions
- Developers expect some sort of credit for utilizing LID practices in form of:
  - A size reduction for the traditional stormwater facilities
  - Credit towards satisfying post-development groundwater recharge requirements.
- In the absence of any existing methods, this study was conducted to develop simple ways to quantify LID benefits in New Jersey.

What LID Benefits can be Quantified?

- LID practices seem to be generally ineffective in controlling the large design peak flow rates.

- LID practices may be effective in:

1. <u>Controlling the runoff volume</u>
2. <u>Providing groundwater recharge.</u>

Runoff Volume Benefits Quantified

- Simple equations and charts were developed to evaluate credit in terms of Curve Number (CN) reduction for two cases:

  - The first case involves diversion of impervious area runoff to a LID facility potentially resulting into a reduction of the CN of the impervious area. Examples: Rooftop Runoff to a dry well; Parking lot runoff to a vegetated buffer strip.

  - The second case involves a small LID such as a bioretention facility within a drainage area potentially decreasing the effective CN value of the drainage area.

First case

Diversion of impervious area runoff to a LID facility

NJ Curve Number Credit Equations for Deep Infiltration LID-IMPs

Notation:

P: Design Precipitation Depth (in),
A_{LID}: The Surface Area of the LID-IMP (sq.ft),
A_{IMP}: The Area of the Impervious Surface Connected tot the LID-IMP (sq.ft),
Qr: Revised Runoff Depth (in),
d = Depth of the LID-IMP (in),
VR = Void Ratio of the Fill Material in LID-IMP,
CNr = Revised CN of the Impervious Area Connected to the LID-IMP.

Equations:

$$Q_r = \{ (P-0.0408)^2 / (P+0.1632) \} - (d\ VR\ (A_{LID}/A_{IMP}))$$

$$CN_r = 100 / (0.5\ P + Q_r - (1.25\ P\ Q_r + Q_r^2)^{(0.5)} + 1)$$

Example:

Problem Statement

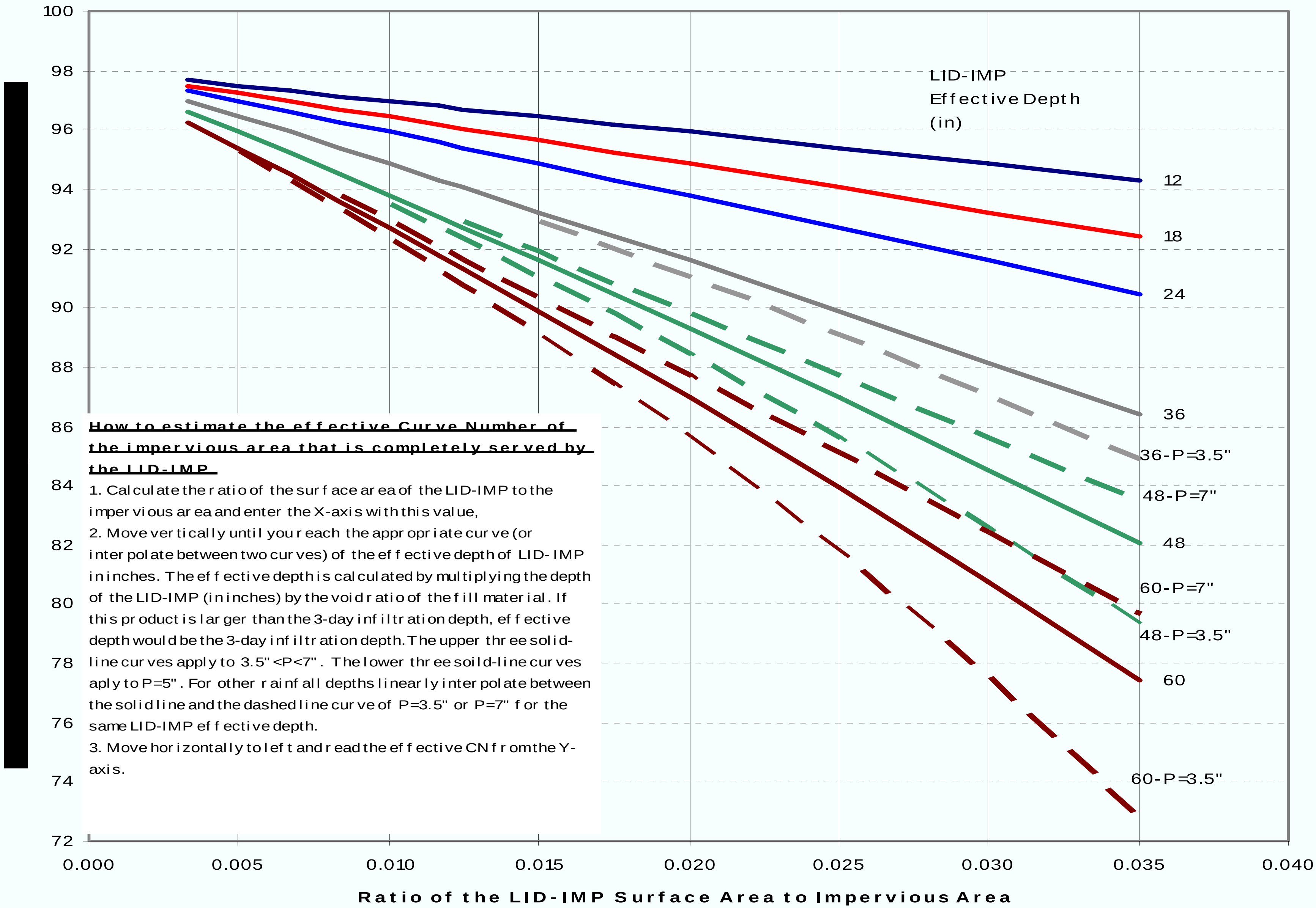
Find the revised CN for a 1500 sq.ft rooftop connected to a dry well with surface area of 15 sq.ft and depth of 12 ft. The well is filled with gravel with a void ratio of 0.33. The design 24-hr precipitation is 4.5 inches.
The expected infiltration depth in three days of operation (considering seepage from sides of the well) is 6 feet.

Solution

Because the expected infiltration depth (6 ft) is larger than well depth multiplied by void ratio (4 ft) the effective depth is not restricted by 3-day infiltration depth.

Q_r = { (4.5-0.0408)2 / (4.5+0.1632)} - (12 x 12 x 0.33 x (15/1500)) = 3.79 inches

CN_r = 100 / (.5 x 4.5 + 4.22 - (1.25 x 4.5 x 4.22 + $4.22^2)^{(0.5)}$ + 1) = 93.76 use 94.



100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Ratio of the LID-IMP Surface Area to Impervious Area
LID-IMP
Effective Depth
(in)
12
18
24
36
36-P=3.5"
48-P=7"
48
60-P=7"
48-P=3.5"
60
60-P=3.5"
How to estimate the effective Curve Number of the impervious area that is completely served by the LID-IMP
1. Calculate the ratio of the surface area of the LID-IMP to the impervious area and enter the X-axis with this value,
2. Move vertically until you reach the appropriate curve (or interpolate between two curves) of the effective depth of LID-IMP in inches. The effective depth is calculated by multiplying the depth of the LID-IMP (in inches) by the void ratio of the fill material. If this product is larger than the 3-day infiltration depth, effective depth would be the 3-day infiltration depth. The upper three solid-line curves apply to 3.5"<P<7". The lower three soild-line curves aply to P=5". For other rainfall depths linearly interpolate between the solid line and the dashed line curve of P=3.5" or P=7" for the same LID-IMP effective depth.
3. Move horizontally to left and read the effective CN from the Y-axis.

Second case

a small LID within a drainage area

NJ Curve Number Credit Equations for Small LID-IMPs

Notation:

P: Design Precipitation Depth (in),
A_{LID}: The Surface Area of the LID-IMP (sq.ft),
A: The Area of the Lot (sq.ft),
Qr: Revised Runoff Depth (in),
d = Depth of the LID-IMP (in),
CN = Post-development CN without the LID-IMP.
CNr = Revised CN of the lthe lot with the LID-IMP.

Equations:

$$Q_r = \{ (P - 0.2\ (1000/CN-10))^2 \ / \ (P+0.8^*\ (1000/CN-10)) \} - (d\ (A_{LID}/A_{IMP}))$$

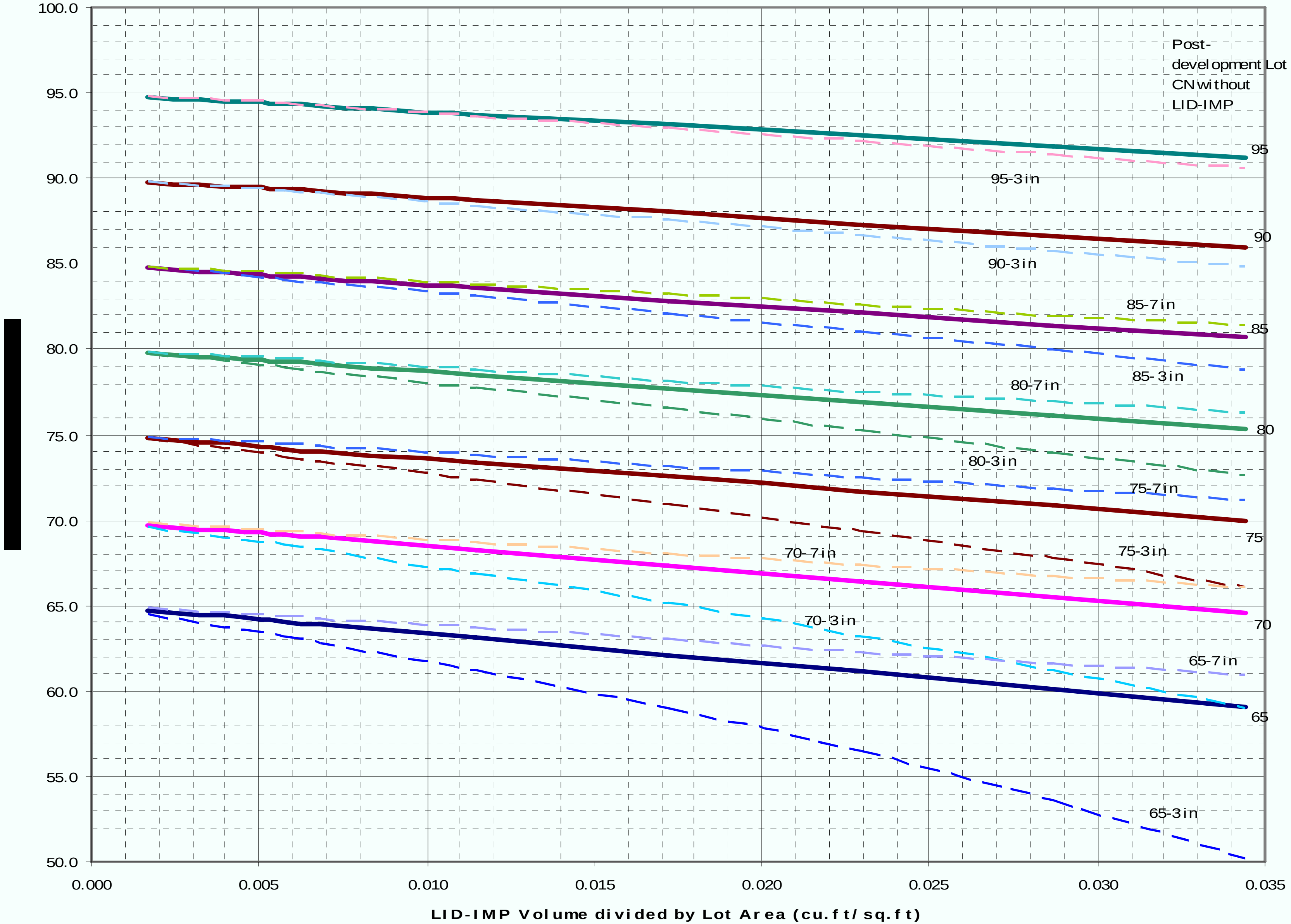
$$CN_r = 100 \ / \ (0.5\ P + Q_r\ - (1.25\ P\ Q_r + Q_r^{\ 2})^{(0.5)} + 1)$$

Example Applications

Example A
Find the revised CN for a 1-ac lot with the post development CN of 85 considering the effects of a two 6-inch-deep bioretention ponds with a combined surface area of 300 sq.ft. The design 24-hr precipitation is 4.5 inches.
Solution
Q_r = {((4.5- 0.2 (1000/85-10))2 / (4.5+0.8* (1000/85-10)) } - (6 (300/(1.0 x 43560))= 2.83 inches
CN_r = 100 / (.5 x 4.5 + 2.83- (1.25 x 4.5 x 2.83 + $2.83^2)^{(0.5)}$ + 1) = 84.1 use 84.

Example B
What if the same ponds were built in a 1/2-acre lot with a post-development CN of 75 and a design 24-hr rainfall of 3 inches?
Solution
Qr = {((3 - 0.2 (1000/75-10))2 / (3+0.8* (1000/75-10)) } - (6 (300/(0.5 x 43560))= 0.88 inches
CNr = 100 / (.5 x 3+ 0.88 - (1.25 x 3 x 0.88+ $0.88^2)^{(0.5)}$ + 1) = 73.4 use 73.

LID-IMP Lot CN Credit



Guide to the LID-IMP CN Credit for the Drainage Basin

This chart shows the effect of one (or more) small LID-IMP in reduction of the effective CN of the driange basin. The revised CN may be used in runoff volume and peak flow rate calculations.
To use this chart first enter the X-axis by the ratio of the LID-IMP volume to the lot area. Then move vertically up to reach the curve that represents the CN of the lot under post-development conditions not considering the LID-IMP (you may have to interpolate between curves for your CN value). The curves shown in solid lines were generated for a design 24-hr rainfall depth of 5 inches. Curves in broken line are for 3- and 7-inch rainfalls. For CN s 90 and above, the 7-inch curves are not given meaning that the 5-inch curve applies to the 5 to 7 inch rainfall depths. For your 24-hr design rainfall depth, you may need to interpolate between the curves for 3 to 5-inch or 5- to 7-inch . Once you select a point on the curve (or between curves) move horizontaly to left and read the revised CN of the lot from the Y-axis.

Example Applications of the Chart

Example A
Find the revised CN for a 1-ac lot with the post development CN of 85 considering the effects of a two 6-ince deep bioretention ponds with a combined surface area of 300 sq.ft. The design 24-hr precipitation is 4.5 inches.
The LID-IMP volume to lot area ratio in this case would be :
(300 x (6/12)) / (43560) = 0.0035; entering the X-axis at the value of 0.0035 and moving vertically up to slightly below the solid line curve (5-inch curve) for CN of 85 and moving horizontally left we can read from the Y-axis a value of 84.3. So the revised CN of 84 can be used.

Example B
What if the same ponds were built on a 1/2-acre lot with a post-development CN of 75 and a design 24-hr rainfall of 3 inches?
In this case the X-axis value would be 0.007. Using the "75-3 in" curve, the revised CN would be 73.4 so use 73.

Groundwater Recharge Benefits Quantified

- The New Jersey stormwater management regulations require the post-development annual groundwater recharge volumes match those of the pre-development conditions.

- A comprehensive method was developed to allow calculation of pre- and post-development recharge volumes in New Jersey.

- Based on that study a simple nomograph was developed that would enable estimation of the annual groundwater recharge volume provided by an infiltration facility receiving runoff from an impervious area operating at near 100% recharge efficiency.

NJ Recharge Spreadsheet

Annual Recharge Page

- Estimation of Annual Recharge Deficit under Post-development Conditions (based on GSR-32)

BMP Calculations Sheet

- Recharge Operation and Efficiency Calculations and BMP or LID-IMP Design

The New Jersey Stormwater Best Management Practices Manual

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If you have any question or comments on the content of this Manual, please e-mail your questions and comments to: swbmpmanual@dep.state.nj.us

Chapters

NJ Recharge Spreadsheet

Screen Capture from the Recharge Deficit Page

New Jersey Groundwater Recharge Spreadsheet Version 2.0 November

Annual Groundwater Recharge Analysis (based on GSR-32)

Select Township ↓	Average Annual P (in)	Climatic Factor
MIDDLESEX CO., PERTH AMBOY CITY	47.8	1.53

Project Name:	Sample Project
Description:	This is a test application
Analysis Date:	09/01/03

Pre-Developed Conditions

Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)
1	1.4	Open space	Woodstown	12.9	65,498
2	0.3	Gravel, dirt	Woodstown	6.9	7,536
3	3.5	Woods-grass combination	Woodstown	13.5	171,255
4	1.4	Open space	Keyport	13.4	68,146
5	0.5	Gravel, dirt	Keyport	7.5	13,657
6	3.3	Woods-grass combination	Keyport	13.9	165,963
7	0				
8	0				
9	0				
10	0				
11	0				
12	0				
13	0				
14	0				
15	0				
Total =	10.4				

Post-Developed Conditions

Land Segment	Area (acres)	TR-55 Land Cover	Soil	Annual Recharge (in)	Annual Recharge (cu.ft)
1	1.5	Impervious areas	Keyport	0.0	-
2	1.6	Gravel, dirt	Woodstown	6.9	40,191
3	3.65	Open space	Keyport	13.4	177,667
4	3.65	Open space	Woodstown	12.9	170,762
5	0				
6	0				
7	0				
8	0				
9	0				
10	0				
11	0				
12	0				
13	0				
14	0				
15	0				
Total =	10.4			Total Annual Recharge (in)	Total Annual Recharge (cu.ft)
				10.3	388,620

Select Soil
Select the Soil from the List. If the TR-55 Land Cover is "Impervious areas" soil does not matter and will not show up and recharge will be set to zero for that segment. Also, hydric soils produce zero recharge.

Annual Recharge Requirements Calculation ↓

-Developed Annual Recharge to Preserve =	100%	Total Impervious Area (sq.ft): 65,340
Post-Development Annual Recharge Deficit=	*103,435*	(cubic feet)

Recharge Efficiency Parameters Calculations (area averages)

RWC=	3.94	(in)	DRWC=	3.94	(in)
ERWC =	0.93	(in)	EDRWC=	0.93	(in)

Procedure to fill the Pre-Development and Post-Development Co

For each land segment, first enter the area, then select TR-55 Land Cover, then select Soil. Start from the top of the table and proceed downward. Don't leave blank rows (with A=0) in between your segment entries. Rows with A=0 will not be displayed or used in calculations. For impervious areas outside of standard lots select "Impervious Areas" as the Land Cover. Soil type for impervious areas are only required if an infiltration facility will be built within these areas.

Screen Capture from the BMP Design Page

Project Name	Description	Analysis Date	BMP or LID Type
Sample Project	This is a test application	09/01/03	

Recharge BMP Input Parameters

Parameter	Symbol	Value	Unit
BMP Area	ABMP	6656.0	sq.ft
BMP Effective Depth, this is the design variable	dBMP	5.2	in
Upper level of the BMP surface (negative if above ground)	dBMPu	-5.2	in
Depth of lower surface of BMP, must be>=dBMPu	dEXC	0.0	in
Post-development Land Segment Location of BMP , Input Zero if Location is distributed or undetermined	SegBMP	0	unitless

Root Zone Water capacity Calculated Parameters

Parameter	Symbol	Value	Unit
Empty Portion of RWC under Post-D Natural Recharge	ERWC	0.93	in
ERWC Modified to consider dEXC	EDRWC	0.93	in
Empty Portion of RWC under Infilt. BMP	RERWC	0.74	in

Recharge Design Parameters

Parameter	Symbol	Value	Unit
Inches of Runoff to capture	Qdesign	0.54	in
Inches of Rainfall to capture	Pdesign	0.67	in
Recharge Provided Avg. over Imp. Area		19.0	in
Runoff Captured Avg. over imp. Area		24.8	in

Solve for ABMP to provide Vdef	Solve for dBMP to provide Vdef	Default Vdef & Aimp

BMP Calculated Size Parameters

ABMP/Aimp	Aratio	0.10	unitless
BMP Volume	VBMP	2,873	cu.ft

CALCULATION CHECK MESSAGES

Volume Balance->	OK
dBMP Check--->	OK
dEXC Check--->	OK
BMP Location--->	Location is selected as distri

Parameters from Annual Recharge Worksheet

Post-D Deficit Recharge (or desired recharge volume)	Vdef	103,435	cu.ft
Post-D Impervious Area (or target Impervious Area)	Aimp	65,340	sq.ft
Root Zone Water Capacity	RWC	3.94	in
RWC Modified to consider dEXC	DRWC	3.94	in
Climatic Factor	C-factor	1.53	no units
Average Annual P	Pavg	47.8	in
Recharge Requirement over Imp. Area	dr	19.0	in

System Performance Calculated Parameters

Annual BMP Recharge Volume		103,435	cu.ft
Avg BMP Recharge Efficiency		76.7%	Represents % Infiltration Recharged
%Rainfall became Runoff		78.3%	%
%Runoff Infiltrated		66.2%	%
%Runoff Recharged		50.8%	%
%Rainfall Recharged		39.7%	%

OTHER NOTES

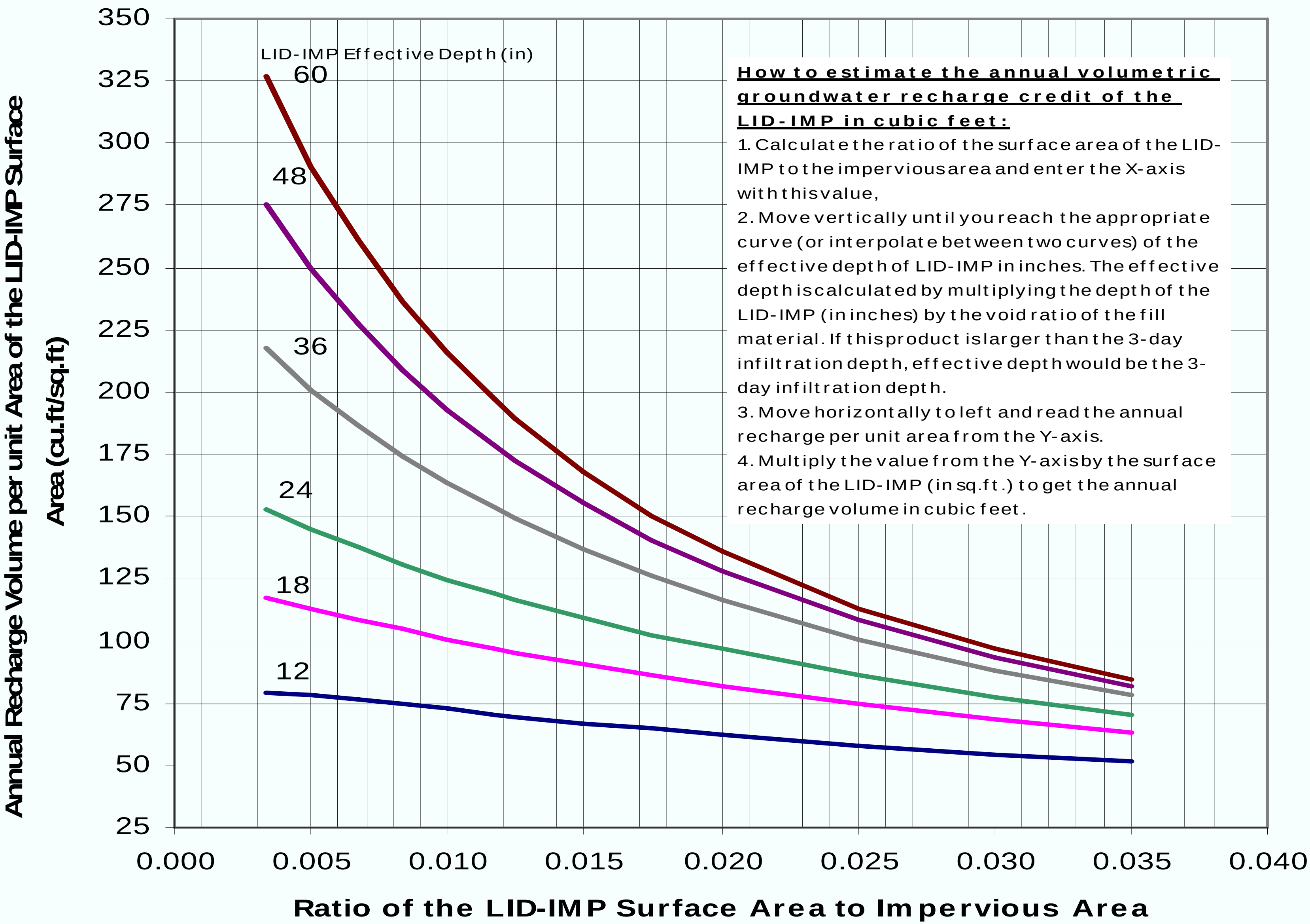
Pdesign is accurate only after BMP dimensions are updated to make rech vo

of BMP infiltration prior to filling and the area occupied by BMP are ignored i

sensetive to dBMP, make sure dBMP selected is small enough for BMP to

Segment Location of BMP if you select "impervious areas" RWC will be min

the soil type and a shallow root zone for this Land Cover allowing consi



LID-IMP Effective Depth (in)
60
48
36
24
18
12
How to estimate the annual volumetric groundwater recharge credit of the LID-IMP in cubic feet:
1. Calculate the ratio of the surface area of the LID-IMP to the impervious area and enter the X-axis with this value,
2. Move vertically until you reach the appropriate curve (or interpolate between two curves) of the effective depth of LID-IMP in inches. The effective depth is calculated by multiplying the depth of the LID-IMP (in inches) by the void ratio of the fill material. If this product is larger than the 3-day infiltration depth, effective depth would be the 3-day infiltration depth.
3. Move horizontally to left and read the annual recharge per unit area from the Y-axis.
4. Multiply the value from the Y-axis by the surface area of the LID-IMP (in sq.ft.) to get the annual recharge volume in cubic feet.
Annual Recharge Volume per unit Area of the LID-IMP Surface Area (cu.ft/sq.ft)
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Ratio of the LID-IMP Surface Area to Impervious Area

Conclusions

- Tools discussed in this paper help in quantifying the LID impacts. They can be used in assigning CN reduction and annual groundwater recharge credits.

- Sample calculations showed that under typical development scenarios several LID facilities per lot would be needed to have a considerable impact in reduction of runoff volumes and providing groundwater recharge.

- The groundwater recharge tools were specifically developed for the New Jersey conditions and data. However, the CN reduction tools may be used anywhere.